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This grant provided for the purchase of an ultra high vacuum sputtering system for the preparation of high quality multilayered magnetic films and thin films. The system allows the preparation of continuous alloys with the use of three magnetron clusters and epitaxial multilayer films using ion beam sputtering. Initial tests of the quality of the films indicate that the films prepared in this system are comparable to those prepared by other workers using similar and different techniques in this area of research. The structural quality of the samples prepared with the system has been measured with low angle x-ray scattering whereas the magnetic properties have been characterized with electrical transport, magnetization, and mageto-optic measurements.

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FINAL REPORT FOR GRANT FROM
DEFENSE UNIVERSITY RESEARCH INSTRUMENTATION PROGRAM

Grant no. AFOSR-89-0138

Date Submitted: 27 July, 1991

Title: Ultra High Vacuum Sputtering System

Equipment Proposal

Institution Name: University of Minnesota
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I. Executive Summary

The UHV sputtering system funded by the Defense-University Research Instrumentation Program (DURIP) under grant no. AFOSR-89-0138 has been purchased and is on site and operational. The total expenditure for the system was $221,000 of which $160,000 was University of Minnesota funds and $61,000 was DURIP funds. The basic system is a UHV sputtering system with both magnetic materials magnetrons and nonmagnetic materials magnetrons (two each) and a dual target differentially pumped ion beam deposition system. There is a sample insertion load lock port for fast turn around times.

Although the system is only recently operational, it is already taken over the central role as the primary producer of high quality thin magnetic films and multilayers utilized in our AFOSR funded research program. Both the thin film and the multilayer research require the highest quality samples in order to conclusively answer a number of questions in fundamental magnetism. In particular, the high quality multilayers produced in this system allow us to be competitive in the very rich and a very exciting research area of magnetic multilayers.

In particular, we have been investigating the effects of structural modifications on the magnetic properties of the films and multilayers to study a number of fundamental magnetics questions. The primary structural modifications of the films have resulted in alterations of the lattice constant; the magnetic properties changed by this are the saturation magnetization and the anisotropy energies. The studies of the multilayers include the giant magnetoresistance effect (or spin-valve effect) and the exchange coupling of in multilayers.

As an example of the quality of films typically produced in this system, figure 1 is a low angle x-ray diffraction pattern of a Ag/Fe multilayer film prepared in the system. In this figure, the x-axis is the scattering angle in degrees and the y-axis is the scattering intensity. The large peaks occurring roughly every 2 degrees, result from the constructive interference of the x-rays scattering from the top of the multilayer and the substrate, i.e., the interference pattern associated with the total thickness of the multilayer film. The smaller oscillations which occur roughly every 0.1 degrees are associated with the interference pattern from the individual layers, i.e., the Ag and Fe layers. The number of the 0.1 degree oscillations are a measure of the sharpness of the interface between the Ag and Fe layers. A simple way to explain this is to consider that the diffraction pattern of the x-rays corresponds to the Fourier transform of the spatial geometry of the multilayers. Therefore, if the interfaces are perfect, then the spatial geometry corresponds to a square wave and there would be a large number of small oscillations in the Fourier transform. As seen in figure 1 there are a very large number of 0.1 degree oscillations.

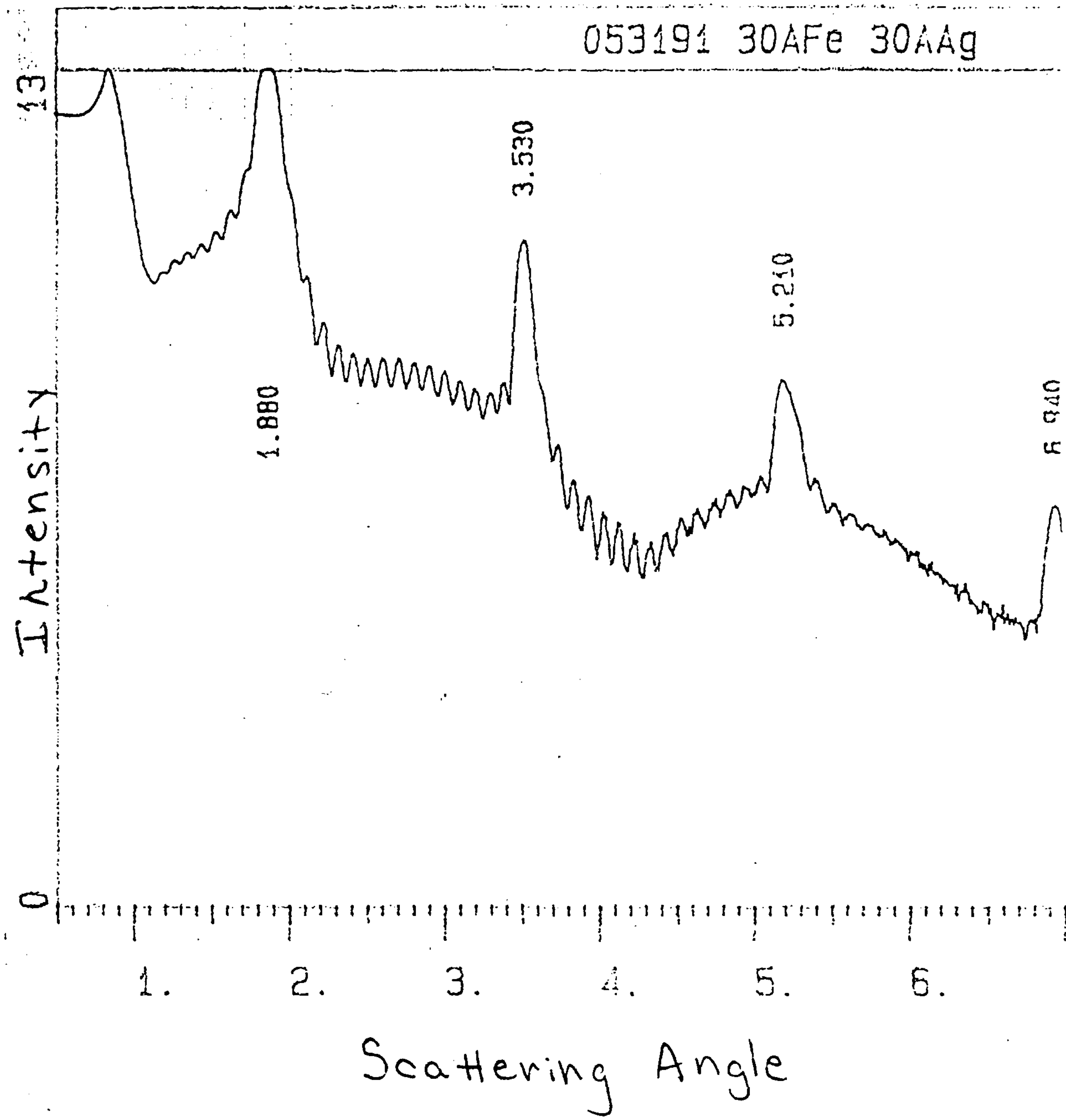

Figure 1. Low angle x-ray scattering diffraction pattern of 3nm Ag/ 3nm Fe multilayer sample.

II. Equipment Purchased.

In what follows is a reproduction of the vendor descriptions of the major pieces of the system.

1. Vacuum Chamber

All stainless steel with metal gaskets, cylindrical shape.
Size to be determined by other requirements.
Possible size diameter 24 inches, height 14 inches.
Top plate supporting sample manipulator capable of commuting substrate from one gun to the other.
Sputtering guns mounted in the upward sputtering configuration.
Pumping on side of chamber.
Capable of holding up to 10 sputtering guns and/or ECR source.
Sputtering guns mounted on a circle either singly or on two 10" flanges in clusters of three.
Capable of being retrofitted with magnetron guns and ECR source.
Each cluster with guns aimed toward the perimeter of the evaporation circle.
Individual guns and clusters individually removable.
Ports for HEED, pumps, gauges, guns, gas outlets, ellipsometer, spare ports, thickness monitors.
Residual gas analyzer.
Gas manifold for two gases.
Better than 5×10^{-9} Torr.
Continuously variable throttle valve to vary pump speed 10%-80%.
Hoist to raise top plate of whole chamber.

2. Sample Holder

X,Y,Z,θ motion capable of moving the sample around above each gun.
Heated to 1000°C, capable of working in oxygen atmosphere, controlled to ±3°C.
Motion controlled with stepping motor.
4" motion away from the guns.
1" sample size.

3. Load Lock

Capable of loading samples on manipulator and removing after evaporation.
Heated to 1000°C, in oxygen environment.
Gas handling capabilities for 1 gas.
Independent pumping to 10^{-6} Torr.
Separated by valve from main chamber.

4. Pumping Module for Main Chamber

4" conflat flange sealed to 500 l/sec turbomolecular pump isolated from chamber with gate valve.
Continuously variable throttle valve to vary pump speed 10%-80%.
Foreline connected to a minimum 25 CFM direct drive dual stage mechanical roughing pump.
Interlocking of pump to avoid accidental venting.

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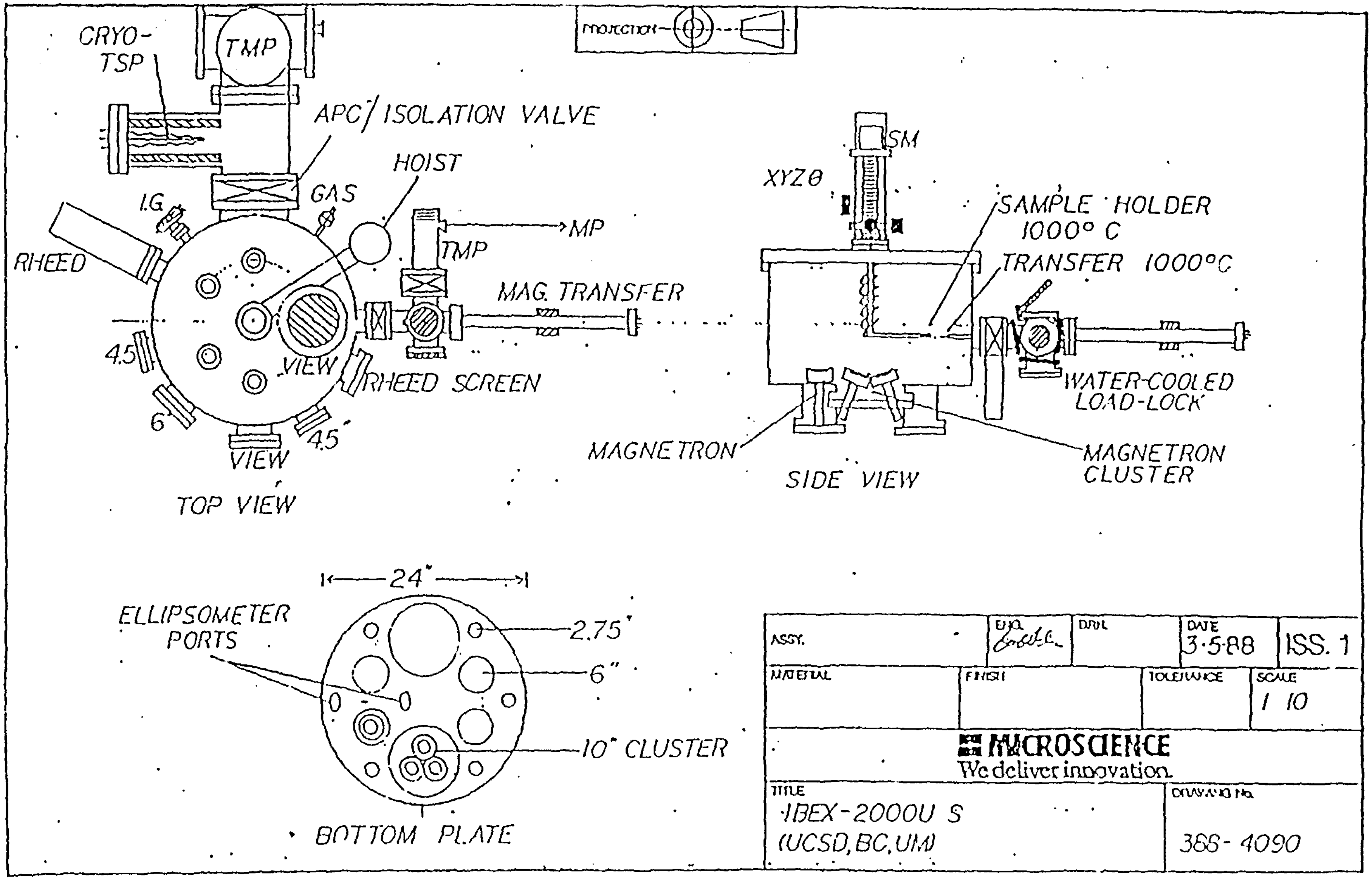

B. Ion Beam Sputtering Retrofit System.

ION BEAM SPUTTERING RETROFIT PACKAGE consisting of:

1. Atom Tech 903U wide beam ion source on .75 meter flexible bellows (allowing future in-situ source repositioning) and suitable for UHV. Source bellows mounts to chamber with a 2.75" CF flange. Beam diameter is 3cm with a beam uniformity of +/- 5% over 80% of the beam diameter, a beam current of >1 mA/cm^2, and a beam energy range of 100eV to 1.5 keV (2 keV with larger power supply). Source outside diameter is 73mm. Source contains (2) pyrolytic graphite grids, (3) cathode filaments and (1) neutralizing filament. Cooling water flow of 2.0 l/min and typical gas flows are from 0.3 to 5.0 sccm. Source operating pressure is in the low 10-4 Torr range. System pressure would be one half to one decade lower.

2. Atom Tech 990 Power Supply/Control Unit for 903U Source with power outputs of 1500V/125mA (Beam), 500V/20mA (Accelerator), 75V/3A (Discharge), 12V/8A (Cathode), and 12V/8A (Neutralizer). Control Resolution (+/-0.1%), Regulation (+/-2.0% of setting), Efficiency (90% from line to load), forced air cooling, input voltage of 115V, 1 phase.

3. Differential pumping chamber (8" height, 8" diameter with removable top cap). Chamber has angled ion gun support tube, fits into hole in chamber bottom and is made of aluminum. The top cap is suitable for exposure to the 1000°C substrate heater.

4. Manual shutter for ion beam system with high temperature compatible shutter plate.

5. Aluminum Block Target holder with manual target positioning (2 targets) via rotary feedthrough.

6. 10" CF Flange to support shutter and target holder feedthroughs and with offset 6" CF port for turbo pump. Includes (2) mini CF flanges for future upgrade to water cooling.

OPTIONS

A. Optional automatic shutter upgrade for ion beam system with high temperature compatible shutter plate.

B. 160 l/s turbopump and controller mounted to 6" CF flange (on 10" CF).

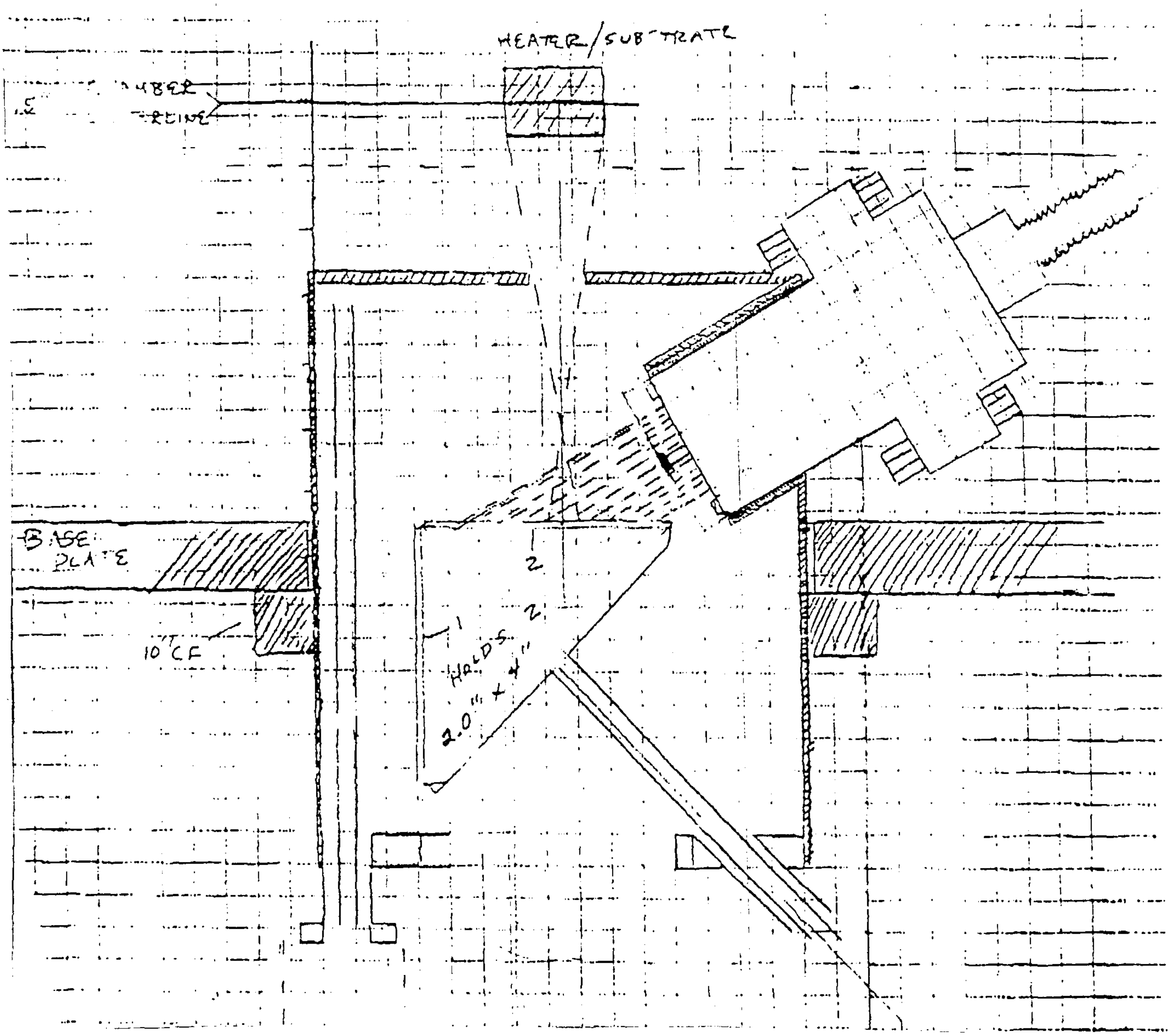

Figure 3. Ion Beam Sputtering Retrofit System.